CLAIMS

What is claimed is:

1. A method, comprising fabricating a cantilever structure having a vertically aligned nanostructure including:

forming a doped layer at a first side of a substrate;

depositing an etch mask layer on a second side of the substrate;

forming a plurality of alignment marks that are coupled to the first side of the substrate;

depositing a catalyst nanoparticle at a deterministic site that is coupled to the doped layer;

growing the vertically aligned nanostructure at the deterministic site with the catalyst nanoparticle;

depositing a first protective layer that surrounds at least a portion of the vertically aligned nanostructure;

patterning the first protective layer to define an outline of a cantilever body;

transferring the outline of the cantilever body from the first protective layer into the doped layer to form the cantilever body from the doped layer;

depositing a second protective layer that coats at least a portion of a surface of the cantilever body;

patterning the etch mask layer to define an outline of a relieved volume;

transferring the outline of the relieved volume from the etch mask layer into the second side of the substrate to remove the relieved volume from the substrate, wherein the cantilever body is substantially not removed.

2. The method of claim 1, further comprising removing the second protective layer; removing the etch mask layer; and removing the first protective layer.

3. The method of claim 1, further comprising, before depositing the catalyst nanoparticle, photolithographically defining the deterministic site.

4. The method of claim 1, wherein growing the vertically aligned nanostructure at the

deterministic site with the catalyst nanoparticle includes growing a vertically aligned carbon nanostructure with a carbon source gas and an etchant gas.

5. The method of claim 1, wherein the substrate includes an intrinsic silicon <100> wafer, the doped layer includes a p+ dopant and transferring the outline of the relieved volume includes wet etching with a heated solution of KOH.

6. The method of claim 1, wherein the doped layer is degeneratively doped to a metallic state.

7. The method of claim 1, wherein the etch mask layer includes Si_3N_4 and patterning the etch mask layer includes photolithography and reactive ion etching.

8. The method of claim 1, wherein the first protective layer includes SiO_2 and removing the first protective layer includes wet etching with a diluted solution of HF.

9. The method of claim 1, wherein the second protective layer includes Si_3N_4 and removing the second protective layer include reactive ion etching.

10. The method of claim 1, further comprising, after growing the vertically aligned nanostructure and before coating the first side of the substrate with the first protective layer, coating the first side of the substrate with a nanostructure deactivating layer that substantially surrounds the vertically aligned nanostructure and then removing a portion of the nanostructure deactivating layer from around a tip of the nanostructure.

11. The method of claim 10, wherein the nanostructure deactivating layer includes Si_3N_4. and removing the portion of the nanostructure deactivating layer includes photolithography and reactive ion etching.

12. The method of claim 1, further comprising, before depositing the catalyst nanoparticle, depositing an electrically conductive layer on the cantilever body layer.

13. The method of claim 12, further comprising, before depositing the first protective layer, removing at least a portion of the electrically conductive layer.

14. The method of claim 13, wherein removing at least a portion of the electrically conductive layer includes forming an electrical interconnect to the vertically aligned nanostructure.

15. The method of claim 1, further comprising, before depositing the cantilever body layer, depositing an etch stop layer on the first side of the substrate.

16. The method of claim 15, wherein the etch stop layer includes SiO_2.

17. The method of claim 1, wherein growing includes incorporating nitrogen containing gaseous species to modify the surface chemistry of the vertically aligned nanostructure.

18. The method of claim 1, further comprising functionalizing at least a portion of the vertically aligned nanostructure with a surface chemistry.

19. The method of claim 1, further comprising removing a carbon layer from the catalyst nanoparticle.

20. The method of claim 19, further comprising chemically modifying a tip region of the vertically aligned nanostructure.

21. A vertically aligned carbon nanostructure scanning probe microscope tip made by the method of claim 1.

22. A vertically aligned carbon nanostructure chemical force microscope tip made by the method of claim 1.

23. A vertically aligned carbon nanostructure magnetic force microscope tip made by the method of claim 1.

24. An apparatus, comprising a cantilever structure including:
a substrate including a cantilever body that includes a doped layer; and
a vertically aligned nanostructure coupled to the cantilever body.

25. The apparatus of claim 24, further comprising another vertically aligned nanostructure coupled to the cantilever body.

26. The apparatus of claim 24, wherein there are no other vertically aligned nanostructures coupled to the cantilever body.

27. The apparatus of claim 24, wherein the vertically aligned nanostructure is coupled to the cantilever body at a photolithographically defined location.

28. The apparatus of claim 24, wherein the vertically aligned nanostructure is located toward an end of the cantilever body and substantially on a longitudinal center line of the cantilever body.

29. The apparatus of claim 24, wherein the vertically aligned nanostructure includes a carbon nanofiber.

30. The apparatus of claim 24, wherein the vertically aligned nanostructure includes a single wall carbon nanotube.

31. The apparatus of claim 24, wherein the vertically aligned nanostructure includes a multi-wall carbon nanotube.

32. The apparatus of claim 24, wherein the vertically aligned nanostructure includes an expanded base and a substantially cylindrical nanostructure coupled to the expanded base.

33. The apparatus of claim 24, further comprising a nanostructure deactivating layer that substantially surrounds a portion of the vertically aligned nanostructure.

34. The apparatus of claim 33, where in the nanostructure deactivating layer includes Si_3N_4.

35. The apparatus of claim 24, further comprising an electrically conducting layer coupled between the vertically aligned nanostructure and the doped layer of the cantilever body.

36. The apparatus of claim 35, wherein the electrically conducting layer includes an electrical interconnect to the vertically aligned nanostructure.

37. The apparatus of claim 24, wherein the doped layer is degeneratively doped to a metallic state.

38. The apparatus of claim 24, wherein the vertically aligned nanostructure is hydrophobic.

39. The apparatus of claim 24, wherein the vertically aligned nanostructure is hydrophilic.

40. The apparatus of claim 24, wherein a tip region of the vertically aligned nanostructure is chemically modified.

41. A chemical force microscope tip comprising the apparatus of claim 24.

42. A chemical force microscope comprising the scanning probe microscope tip of claim 41.

43. A scanning probe microscope tip comprising the apparatus of claim 24.

44. A scanning probe microscope comprising the scanning probe microscope tip of claim 43.

45. A magnetic force microscope tip comprising the apparatus of claim 24.

46. A magnetic force microscope comprising the scanning probe microscope tip of claim 45.

47. A method, comprising fabricating a cantilever structure having a vertically aligned nanostructure including:

depositing a cantilever body layer that is coupled to a first side of a substrate;

depositing an etch mask layer on a second side of a substrate;

forming a plurality of alignment marks that are coupled to the first side of the substrate;

depositing a catalyst nanoparticle at a deterministic site that is coupled to the cantilever body layer;

growing the vertically aligned nanostructure at the deterministic site with the catalyst nanoparticle;

depositing a first protective layer that surrounds at least a portion of the vertically aligned nanostructure;

patterning the first protective layer to define an outline of a cantilever body;

transferring the outline of the cantilever body from the first protective layer into the cantilever body layer to form the cantilever body from the cantilever body layer;

depositing a second protective layer that coats at least a portion of a surface of the cantilever body;

patterning the etch mask layer to define an outline of a relieved volume;

transferring the outline of the relieved volume from the etch mask layer into the second side of the substrate to remove the relieved volume from the substrate, wherein the cantilever body is substantially not removed.

48. The method of claim 44, further comprising removing the second protective layer; removing the etch mask layer; and removing the first protective layer.

49. The method of claim 47, further comprising, before depositing the catalyst nanoparticle, photolithographically defining the deterministic site.

50. The method of claim 47, wherein growing the vertically aligned nanostructure at the deterministic site with the catalyst nanoparticle includes growing a vertically aligned carbon nanostructure with a carbon source gas and an etchant gas.

51. The method of claim 47, wherein the substrate includes an intrinsic silicon <100> wafer

and transferring the outline of the relieved volume includes wet etching with a heated solution of KOH.

52. The method of claim 47, further comprising forming a doped layer in the cantilever body layer.

53. The method of claim 1, wherein the doped layer is degeneratively doped to a metallic state.

54. The method of claim 47, wherein the etch mask layer includes Si_3N_4 and patterning the etch mask layer includes photolithography and reactive ion etching.

55. The method of claim 47, wherein the first protective layer includes SiO_2 and removing the first protective layer includes wet etching with a diluted solution of HF.

56. The method of claim 47, wherein the second protective layer includes Si_3N_4 and removing the second protective layer include reactive ion etching.

57. The method of claim 47, further comprising, after growing the vertically aligned nanostructure and before coating the first side of the substrate with the first protective layer, coating the first side of the substrate with a nanostructure deactivating layer that substantially surrounds the vertically aligned nanostructure and then removing a portion of the nanostructure deactivating layer from around a tip of the nanostructure.

58. The method of claim 57, wherein the nanostructure deactivating layer includes Si_3N_4. and removing the portion of the nanostructure deactivating layer includes photolithography and reactive ion etching.

59. The method of claim 47, further comprising, before depositing the catalyst nanoparticle, depositing an electrically conductive layer on the cantilever body layer.

60. The method of claim 59, further comprising, before depositing the first protective layer,

removing at least a portion of the electrically conductive layer.

61. The method of claim 60, wherein removing at least a portion of the electrically conductive layer includes forming an electrical interconnect to the vertically aligned nanostructure.

62. The method of claim 47, further comprising, before depositing the cantilever body layer, depositing an etch stop layer on the first side of the substrate.

63. The method of claim 62, wherein the etch stop layer includes SiO_2.

64. The method of claim 47, wherein growing includes incorporating nitrogen containing gaseous species to modify the surface chemistry of the vertically aligned nanostructure.

65. The method of claim 47, further comprising functionalizing at least a portion of the vertically aligned nanostructure with a surface chemistry.

66. The method of claim 47, further comprising removing a carbon layer from the catalyst nanoparticle.

67. The method of claim 66, further comprising chemically modifying a tip region of the vertically aligned nanostructure.

68. A vertically aligned carbon nanostructure scanning probe microscope tip made by the method of claim 47.

69. A vertically aligned carbon nanostructure chemical force microscope tip made by the method of claim 47.

70. A vertically aligned carbon nanostructure magnetic force microscope tip made by the method of claim 47.

71. An apparatus, comprising a cantilever structure including:
a substrate including a cantilever body; and
a vertically aligned nanostructure coupled to the cantilever body.

72. The apparatus of claim 71, further comprising another vertically aligned nanostructure coupled to the cantilever body.

73. The apparatus of claim 71, wherein there are no other vertically aligned nanostructures coupled to the cantilever body.

74. The apparatus of claim 71, wherein the vertically aligned nanostructure is coupled to the cantilever body at a photolithographically defined location.

75. The apparatus of claim 71, wherein the vertically aligned nanostructure is located toward an end of the cantilever body and substantially on a longitudinal center line of the cantilever body.

76. The apparatus of claim 71, wherein the vertically aligned nanostructure includes a carbon nanofiber.

77. The apparatus of claim 71, wherein the vertically aligned nanostructure includes a single wall carbon nanotube.

78. The apparatus of claim 71, wherein the vertically aligned nanostructure includes a multi-wall carbon nanotube.

79. The apparatus of claim 71, wherein the vertically aligned nanostructure includes an expanded base and a substantially cylindrical nanostructure coupled to the expanded base.

80. The apparatus of claim 71, further comprising a nanostructure deactivating layer that substantially surrounds a portion of the vertically aligned nanostructure.

81. The apparatus of claim 80, where in the nanostructure deactivating layer includes Si_3N_4.

82. The apparatus of claim 71, further comprising an electrically conducting layer coupled between the vertically aligned nanostructure and the cantilever body.

83. The apparatus of claim 82, wherein the electrically conducting layer includes an electrical interconnect to the vertically aligned nanostructure.

84. The apparatus of claim 71, wherein the cantilever body includes an etch stop layer.

85. The apparatus of claim 71, wherein the cantilever body includes a doped layer.

86. The apparatus of claim 85, wherein the doped layer is degeneratively doped to a metallic state.

87. The apparatus of claim 71, wherein the vertically aligned nanostructure is hydrophobic.

88. The apparatus of claim 71, wherein the vertically aligned nanostructure is hydrophilic.

89. The apparatus of claim 71, wherein a tip region of the vertically aligned nanostructure is chemically modified.

90. A chemical force microscope tip comprising the apparatus of claim 71.

91. A chemical force microscope comprising the scanning probe microscope tip of claim 90.

92. A scanning probe microscope tip comprising the apparatus of claim 71.

93. A scanning probe microscope comprising the scanning probe microscope tip of claim 92.

94. A magnetic force microscope tip comprising the apparatus of claim 71.

95. A magnetic force microscope comprising the scanning probe microscope tip of claim 94.